EFFECT OF TIDE ON FLOOD MODELLING AND MAPPING IN KOTA TINGGI

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To my beloved family and friends,

Thank you for your encouragements and supports.

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ABSTRACT

This study aimed at mapping the Kota Tinggi flood in 2006/07 that had caused massive damages to properties and the environment. The flood was associated with unusually high intensity and continuous rainfall. Therefore, a reliable technique of floodplain mapping is crucial for the improvement of flood control strategies and preparing an evacuation plan. The main objective of this study is to compare the effect of tide on flood modelling analysis. The inundated areas were mapped for various annual recurrent intervals (ARIs) using peak flow data from July 1965 to Jun 2010. The study used Light Detection and Ranging (LiDAR) data for flood modelling. HEC-HMS, HEC-RAS, and HEC-GeoRAS were used to develop the flood modelling. The results reaffirm that the GEV model is the best for fitting the annual flood. The HEC-HMS hydrologic model was calibrated and validated using observed hydrographs in September 2002 and January 2003, respectively. Upon successful calibration and validation, the model was used to simulate flood hydrograph in January 2007. The modelling took into account tidal effect. When tidal effect was not considered, the simulated flood depth was 43 % lower than the observed flood. However, the inclusion of tidal effect has reduced the simulation error with average similarity of 91.4%. The simulation results show that the river flow starts to over bank for ARIs exceeded 25 year.

ABSTRAK

Kajian ini bertujuan untuk memeta dan memodelkan banjir di Kota Tinggi pada tahun 2006/07 yang telah mengakibatkan kerosakan besar pada harta benda dan alam sekitar. Banjir ini disebabkan keamatan hujan yang tinggi dan beterusan. Oleh itu, teknik pemetaan banjir adalah penting dalam menambahbaik strategi kawalan banjir dan menyediakan pelan pemindahan. Objektif utama kajian ini ialah untuk membandingkan kesan pasang surut air ke atas pemodelan banjir. Kawasan banjir telah dipetakan dalam pelbagai tahun kala kembali dengan menggunakan data aliran puncak dari Julai 1965 hingga Jun 2010. Kajian ini menggunakan data Light Detection and Ranging (LiDAR) bagi pemodelan banjir. Perisian HEC-HMS, HEC-RAS, dan HEC-GeoRAS telah digunakan bagi membangunkan model pemetaan banjir. Analisis frekuensi mengesahkan bahawa model GEV adalah yang terbaik berdasarkan ujian GOF, dan sesuai digunakan bagi menentukan nilai ARI. Model HEC-HMS telah dikalibrasi dan divalidasi, masing-masing menggunakan hidrograf cerapan bulan September 2002 dan Januari 2003. Setelah prosess kalibrasi dan validasi, model ini telah diguna bagi mensimulasi hidrograf banjir pada Januari 2007. Model banjir telah mengambil kira kesan air pasang surut. Tanpa mengambil kira kesan pasang surut, hasil simulasi telah terkurang angar sebanyak 43% daripada data cerapan. Dengan kesan pasang surut diambil kira, ralat pemodelan dapat dikurangkan dengan peratus kesamaan sebanyak 91.4%. Keputusan simulasi menunjukkan bahawa aliran sungai mula melimpahi tebing untuk ARI melebihi 25 tahun.

TABLE OF CONTENTS

LIST OF TABLES

TABLE NO. **TITLE** **PAGE**

LIST OF FIGURES

LIST OF ABBREVIATIONS

ARI	-	Average Recurrent Interval
CDF	-	Cumulative Distribution Function
DEM	-	Digital Elevation Model
DID	-	Department of Irrigation and Drainage
EAP	-	Emergency Action Plan
GEV	-	General Extreme Value
GIS	-	Geographical Information System
GOF	-	Goodness of Fit Test
K-S	-	Kolomogorov-Sminov
LiDAR	-	Light Detection and Ranging
MASMA	-	Manual Saliran Mesra Alam
PDF	-	Probability Density Function
SMA	-	Soil Moisture Accounting
SWMM	-	Storm Water Management Model
U-H	-	Unit Hydrograph

LIST OF SYMBOLS

Q_p	-	Flood Peak Flow
Q_v	-	Flood Volume
Q_d	-	Flood Distribution
n	-	Manning's roughness coefficient
d	-	Depth of Flood
V	-	Velocity of Flood Water
k	-	Continues Shape
σ	-	Continues Scale
μ	-	Continues Location
T_c	-	Time of Concentration
T_r		Return Period

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

The terms flood or flooding cover a very wide range of phenomena. Flood has been recognised as the number one disaster in many parts of the world causing tremendous damages to properties and the environment and losses of life (Smith and Ward, 1998). Globally, in 1980, there were at least 60 major flood disasters and each involving losses of more than 1000 lives (Bates et al., 1997). The phenomena occurred mainly in Asia and South America (UNEP, 1991). The modification of terrain or contour could pose severe damage to Natural River. Moreover, with global warming, the rate of sea level rise is expected to be higher in the future (Nijland, 2005).

Future rainfall is also predicted to be more intense and would result in increasing flood peak, flood volume and duration. Over the past few years, there is evidence of increase rainfall intensity and coupled with large impervious area has resulted in more extreme and frequent flood occurrence (Knebl et al., 2002). Flooding is an inevitable phenomenon, which can contribute to an extreme and diverse impact such as destruction to human lives, property, and livestock. Therefore, flood simulation is important in order to estimate the present and future floods.

Hydrology and hydraulics modelling needs reliable data for model calibration and validation. There are about 200 rivers system in Malaysia, 150 in Peninsular and the rest in Sabah and Sarawak. The major floods were recorded in Malaysia in 1926, 1931, 1947, 1957, 1967, 1971, 1973, 1979, 1983, 1995, 1998, 2003, and 2005 (Abdullah, 2006) and most recently in December 2014 which caused tremendous damages especially in Kelantan and Pahang. The January 1971 flood that hit Kuala Lumpur and many other states had resulted in a loss of more than RM 200 million and 61 deaths (Yatim, 2012). The flood in Johor (2006/07) was due to “abnormally” heavy rainfall events. The estimated total lost due to this disasters was RM 1.5 billion and RM 237.1 million was for damaged infrastructure alone (Yatim, 2012). It was classified as the highest cost of flood events in Malaysia.

Flood phenomena that are often estimated with simplified assumptions, and parsimonious models may not be able to accurately assess the complex hydrodynamic processes such as tidal effect in river (Chihao et al., 2009). Flood simulation is important in order to estimate the present and future floods. Hydrologic and hydraulics modelling needs reliable parameter data for model calibration and validation. HEC-RAS is one of the most widely used models. It has been tested in analysing hydraulic characteristic of rivers. This model computes water surface profiles and energy grade lines in 2-D, unsteady-state, and gradually varied flow analyses. Once the model structure and order have been identified, the parameters and characteristics of the model can be estimated, calibrated, and validated in some manner (Malcom, 2007).

Johor river basin covers 6319 km^2, lies in the eastern part of Johor state. The basin is exposed to the northeast trade wind which brings heavy rain in the months of November to March (Nachtnebel et al., 2007). The average rainfall is 2,470 mm per year. Kota Tinggi is a district in Johor State. The distance between Kota Tinggi town to Rantau Panjang gauging station is about 12 km along the river alignment. The area upstream of this station is about 3489 km^2, which consists of agriculture, business and mining activities. In 2006/07 flood event, Kota Tinggi was drowned into a massive flood and became one of the highly adverse floods in Malaysia. The region experienced two huge flood events in late 2006 and early 2007 with the observed total rainfall about 400 mm within 3 days (Shafie et al., 2007).

Thus, the present analysis develops 2D flood mapping using hydrodynamics model. In the meantime, 2D numerical hydraulic models are considered advanced enough for the prediction of flood extent, depth, and flow velocities (Bates et al., 1997; Penton and Overton, 2007).

1.2 Problem Statement

The floods at Kota Tinggi in December 2006 and January 2007 have caused heavy damages to business and local infrastructures. A total of 11,724 victims in 2006 flood event and 7,915 victims in January 2007 were evacuated (Yatim et al., 2012). This problem is expected to recur year after year. Researchers and modellers had critically discussed about formulating integrated flood mitigation to reduce short term and long-term problems.

Currently there is an increasing interest to develop a new hydrodynamic model in order to achieve better flood modelling results in terms of visualization and characterization. The purpose of this formulation is to incorporate the concept of storm water management, comprising best mix strategies using both structural and non-structural measures. The integration of floodplain and storm water management simulation becomes important in giving new dimension on detecting flood events and handling unexpected events such as bund breach, or failure of flood and detention facilities.

High or spring tide may aggravate flood problems. The effect may cause serious damage compare to normal flood. As mentioned above, flood mapping at Kota Tinggi town is important to predict the possibility of flood occurrences and formulate emergency action plan (EAP), insurance policy and in development planning. a major planning tool to solve the problems and to achieve the objectives of this study.

1.3 Purpose and Objectives of Study

This study concerned with developing appropriate method for flood mapping. In doing that, the following specific objectives are outlined:

1. To estimate the average recurrent interval (ARI) of annual flood using flood frequency analysis.
2. To examine the effect of tide on the flood modelling results.
3. To map the 2006/07 flood and the simulated floods for 25, 50, 100 and 200 year return periods.

1.4 Scope of Study

The study area was in Johor River catchment. The catchment area was selected because it is prone to flood and the availability of data. In this study, hydrology and GIS data for modelling and analysis, such as landuse, river catchment, river profile, rainfall, and stream flow were compiled, corrected, and validated. For frequency analysis models, Log Pearson 5, GEV, Lognormal, and Weibull were used. In order to perform goodness of fit test for determining the best distribution model for peak flow, Kolmogov-Smirnov (K-S) test was used. Then, the return period was calculated based on the best fitted model. The peakflows for 25, 50, 100, and 200 ARIs were then predicted. The hydrographs were modelled using HEC-HMS software and the flood mapping used HEC-RAS. The boundary condition was simulated into two options, which considered two conditions, with tidal and without tidal effect. In addition, HEC-GeoRAS was used to simulate the floodplain in 1D model and 2D model using LiDAR data.

1.5 Importance of the Study

The study provides knowledge and understanding of the used of HEC-HMS, HEC-RAS, and HEC-GeoRAS software for hydrological and flood modelling. The study helps in understanding the components and characteristics of tidal on flood modelling. Thus, throughout this study, the information of flood maps, flood depth, and flood extend can be determined for flood forecasting. In additional, local authorities could have a better planning for flood mitigation, and flood evacuation strategies.

1.6 **Structure of Thesis**

The structure of thesis consists of five chapters as follows;

Chapter 1 introduces background of the study area, problem definition related to flood modelling, objectives, scopes and the important of study.

Chapter 2 discusses past research related to flood modelling. The literature highlight flood history in Malaysia, especially at Kota Tinggi. Various techniques of frequency analysis for estimating peakflow of several of ARIs are discussed. The literature review also include application of Hydrological and Hydraulic models for flood modelling. The effects of tide on flood modelling results are also discussed.l

Chapter 3 explains the methodology used in the study. These include describing the study catchment, application of digital elevation model, frequency analysis, hydrological modelling, hydraulic modelling, and lastly flood mapping.

Chapter 4 presents the results of the study. The main results discussed are on frequency analysis, the modelling of hydrograph and flood mapping.

Chapter 5 concludes the study results in relation to the study objectives. Recommendations for future study are also presented.

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